BIOMASS POTENTIAL ASSESSMENT FOR LOCATING BIOREFINERY PLANT IN HUNGARY

[1]*N. Kohlheb*, [2]*M. Belényesi*, [1]*L. Podmaniczky*, [1]*B. Sipos*, [1]*K. Balázs*
[1]Institute of Nature Conservation and Landscape Management, Szent István University, Páter Károly utca 1, 2100, Gödöllö, Hungary, e-mail: balazs.katalin@mkk.szie.hu
[2]Institute of Geodesy, Cartography and Remote Sensing, Bosnyák tér 5, 1149, Budapest, Hungary

ABSTRACT

To find a suitable site for a 150,000 metric ton dry material per year (t dm/yr) input capacity biorefinery plant in Hungary is a challenging task. Not only biomass potentials have to be assessed, competing uses, sustainability aspects, public opinion and future threats to feedstock availability should be also taken into account. As a result of our calculations, currently there is enough feedstock available for the targeted input capacity to operate in an ecologically sustainable way. However, several factors may threaten the future of feedstock availability. In the long run enhanced price competition is anticipated for biomass among biorefinery, livestock keeping, timber industry and biomass based renewable energy production. The majority of stakeholders accept in general biorefinery as a promising solution for substituting fossil based plastics, still local interests give priority to a balanced agricultural production including higher shares of husbandry.

Keywords: bioenergy, biomass potentials, biorefinery plant, planning approaches, sustainability

1. INTRODUCTION

Life cannot be imagined without the use of biomass and bioenergy even in today's modern societies. Fossil energy is only a temporary substitute for biomass in developed countries where its sources contributed to a great extent to food production during the era of industrialization in agriculture [8, 20]. Beyond food provision, biomass is increasingly becoming important again from energetic point of view:, being one of the most cost-efficient and most easily available resource. The energetic use of biomass also has significant share (60-90%) in developing countries [21].

Modern energetic use of biomass has long traditions in Hungary, as well. Roughly one million metric tons of firewood per year is burnt by households in the country. Since 2003 several power plants in Hungary have shifted from coal powder to biomass chips firing to produce electricity using 1.425 metric tons of wood annually, of which 1.3 million metric tons originate from woodlands [17, own calculation]. The energetic efficiency of using biomass this way is only 20-25% as waste heat is not utilised in most of the cases. Apart from food, energetics and timber (e.g. furniture) industry, biomass is also an increasingly important input for biorefinery and bioplastics with the aim of trying to substitute conventional petrochemical products whose price is continuously rising. Available biomass is increasingly used for all three purposes (food, energetics, material) inducing enhanced competition in the future. The significance of biomass remains and will continuously grow in all fields in our economies. This fact underlines the utmost importance of sustainable use as biomass can be considered renewable resource only among certain circumstances; otherwise complete devastation of the resource and related wildlife communities is a real threat. Biomass as a resource is embedded in the natural environment with thousand links and its excessive exploitation induces a domino effect of decay in related ecosystems [12].

It is a timely issue to evaluate the above uses according to efficiency in order to set a priority list that puts first the possibly most efficient use from environmental, social and economic aspects alike. Important principles to be considered include the waste management pyramid and the application of cascade systems in integrated biomass use [11]. For this very reason the use of biomass should be planned more carefully compared to other renewable resources (e.g. solar or wind power), where the principles of sustainable use should be respected in particular.

The objective of this paper is to present the critical points of biomass use and deliberative planning based on the example of a case study in Hungary. This case study is a biorefinery plant with a 150 t dm/year input capacity able to use feed-stock of hard wood and straw. The plant converts these raw materials to sugar based intermediaries, a basis for polymerisation into cellulose bioplastics like polyesters, polyethylene or other end products. As the material use of biomass is gaining increasing importance, we investigate questions of locating the biorefinery based on feedstock availability. We describe in depth the steps of planning related to choosing a proper feedstock mix that is available in a sustainable manner to ensure continuous feedstock supply. The paper begins with exploring the planning methodology from literature. In the second part the results of the case study are presented in detail. In the third part of the study the applicability of the results is evaluated and discussed from the aspect of sustainability.

2. METHODS

2.1. Planning approaches

Investments are usually proceeded by careful planning. The major share of planning is related to creating the technical infrastructure and profitability calculations of the operations. In terms of developments in renewable energy production, and for investments in biomass use in particular, planning of sustainable feed stock supply is an important issue. In the event of a complex use of renewable resources an even wider aspect for planning is needed, as beyond technical and economic parameters social acceptance also emerges as an issue, since the negative effects of technologies that transform the environment are rather perceived by the local society. Consequently, these groups are steady opponents to investments with disadvantageous local effects and very often manage to thwart them [6].

The three dimensions of the scale along which planning approaches can be characterized are content, goal and the planner (Fig. 1).

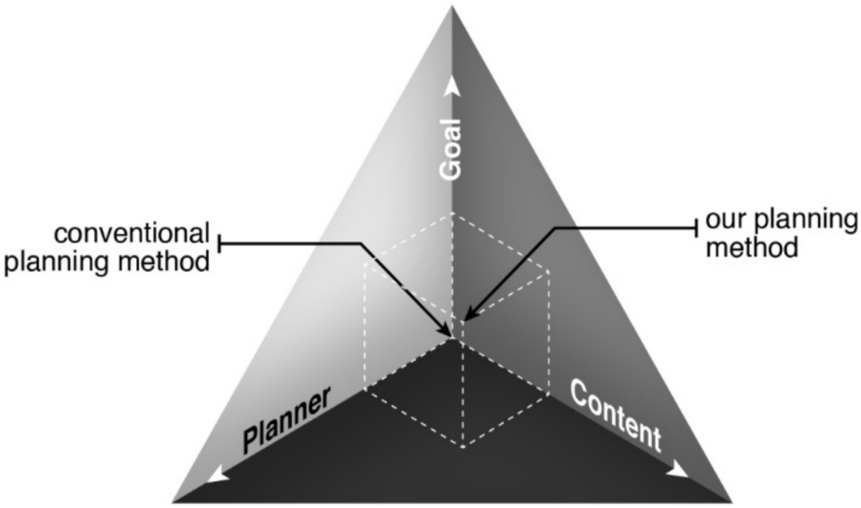

Figure 1. Three dimensions of planning approaches

The content of each plan can be very different and also dependent on the goal of planning and the personality of the planner. The goal of planning can be oriented for profit generation in contrast with the non-profit operation prioritizing self-supply. In order to have an open and innovative planning atmosphere, the group of planners should not be consisted of a narrow group of technical people. Additionally, concerned stakeholders shall be involved in the process. There are several levels of involvement [2] of which partnership or civil control is the real level of co-operation.

On the one end of the scale is when the plan prepared by a group of experts (planner axis) is purely concentrating on the technical and economic parameters (content axis), whose primary aim is to produce the investors' profit (goal axis). In this case the planner tries to find an optimal location for investment chiefly from economic aspects while meeting the local demands or striving for self-supply is not part of the concept. In this case the overexploitation of local resources (both natural and human) is not a direct threat to the planned investment as after depletion of resources the plant is moved to a new site in the next resort.

In contrast, on the other end of the scale is the community based participatory planning approach with holistic view on integrating environmental, ecological and social aspects, where profit is secondary and economic issues are handled at the level of covering costs (goal axis). Autonomy is a central element to this planning approach that prioritizes the demands of local community over production for sale (content axis). The planning process is bottom-up and involves the local community that participates actively and decides about the investment and its scales (planner axis). Such investment and operation will then be

inherently linked to local resources. Any risk or damage to the local resources will threaten the investment as well, so there is direct feedback between the investment and its environment.
Between the above described extremes there is a series of transitional approaches. The reason for this – concerning the content axis – is that renewable energy production investments planned purely on business aspects are not capable of accommodating to the natural and social environment, therefore, their operability in the long run is uncertain. On the other end – concerning the goal axis – no purely autonomy-based planning mechanisms appear in reality as cost-efficiency is important also with community investments. In many cases it is not even about self-supply as some local demands cannot be met solely based on own resources. Such demands must be fulfilled through import with the help of merchandising the extra local production (for example buying fuel for the surplus of produced green electricity).
Planning involves three main aspects: planning of available biomass potential, estimating the environmental effects and setting the optimal location. In this study we considered only the available biomass potential planning.

2.2. Biomass potentials

There are several approaches to calculating biomass potential. The largest amount is usually called total biomass potential which is calculated on the basis of the total annual production and which also involves the amount of by-products and waste produced (Fig. 2). This potential is called physical or theoretical biomass potential [25]. In this relation by-products and waste are categorized as primary (produced by agriculture), secondary (produced during the processing of agricultural raw materials) and tertiary (produced during consumption).

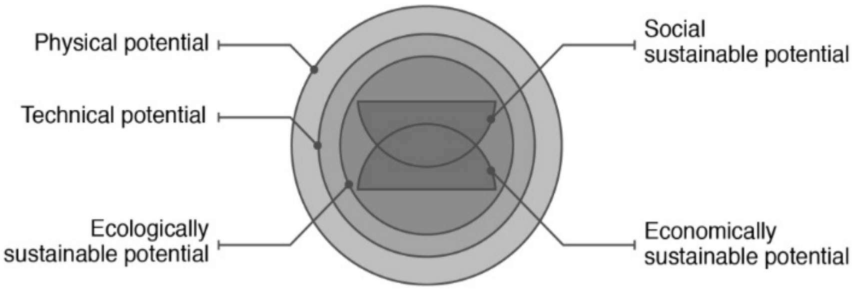

Figure 2. Different types of potential and their relations

The next category is the technically available biomass potential, that involves the harvestable amount of biomass with regard to the technical specifications. This is calculated in the literature in various ways [25]. Ref. [5] defines technical potential as the amount remaining after the demands of competing uses are deducted from the total. Beyond biomass use for industrial and food purposes, environmental and ecological demands also belong to competing uses. In contrast, according to Ref. [25], the technical potential means the amount of a certain type of energy (e.g. thermal energy, biofuel or electricity) that can be produced from the available raw material with the technology in question.
The third type is available potential given by the volume of available amount of biomass that can be collected with regard to both technical and economic aspects [25].

2.3. Methodology

Our study is more than about planning the technical and economic aspects, as potential environmental effects are also considered. The aim of planning is also more than merely seeking for profit, as the planned technology on the one hand will enable the substitution of fossil resources and will also give opportunity for the realization of a more efficient cascade type [11] use of biomass. Local meetings were organised in the target area to collect opinions about the development. Although they did not take part in the full planning process itself, they were involved in a very early phase of the planning process when concrete data on the planned production details were not yet available. We locate our planning approach in Fig. 1 compared to the profit oriented conventional planning, which is in the origin, more or less to an equal distance from the origin in each direction highlighting the diversity of goals, planners and the broader focus of content.

Based on the above biomass potentials we devised the following methodology. As a first step the physical potential was calculated. This involves the total amount of biomass that can be produced in the given study area and can be used by the given technology.

From the physical potential the technical potential is determined that involves the harvestable amount of biomass with regard to the technical specifications. The losses during harvest (e.g. height of stubble during straw harvest) and technical collectability of biomass should be considered. In the next step the available biomass potential is calculated from the technical potential by deducting the demands of competing uses in the area, such as bedding straw demand of animal husbandry and firewood demand of heating- and power plants, etc. Finally, it is necessary to investigate whether the full exploitation of the available biomass is sustainable from environmental, economic and social aspects [25, 23]. The workflow for defining the available sustainable potential is depicted in Fig. 3.

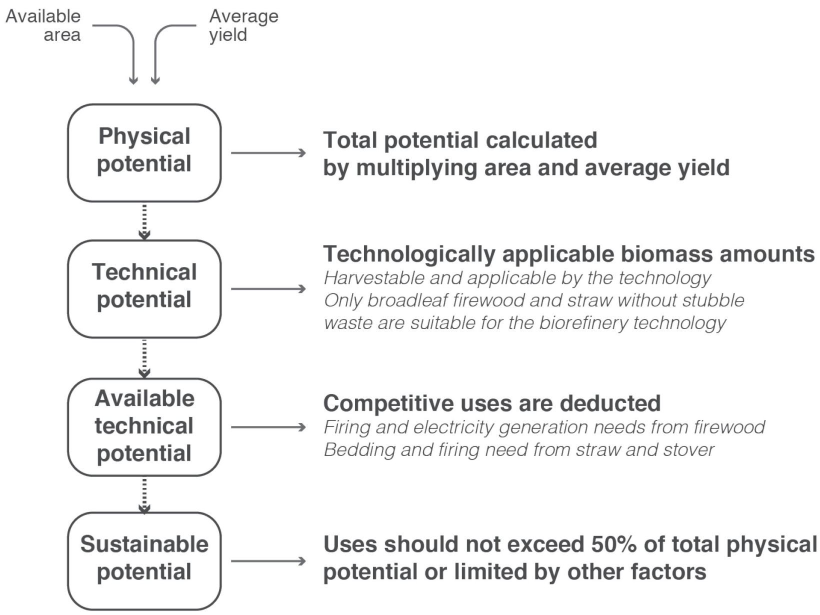

Figure 3. Methodology for defining the available sustainable potential

In terms of ecological sustainability it is an evitable question how much biomass can be consumed by the society without harming the concerned ecosystems. This can be assessed with the help of the Human Appropriation of Net Primary Production (HANPP) model (Haberl et. al. 2004), or more precisely with one of its components, the net primary product (NPP_t) that involves the amount of biomass remaining for natural ecosystems beyond human use. This is the amount of energy flow that is available for the normal functioning of natural ecosystems. The minimum of NPP_t means that any further decrease in this amount would lead to the damage and shrinkage of ecosystems [27]. For the detailed introduction of the method see [11].

According to Ref.[12] the value of NPP_t shows positive correlation with species diversity. The study suggests that a HANPP value over 50% might lead to biodiversity decline [12]. The HANPP was 49% in Hungary in 2005 meaning that out of the net primary product (NPP) produced by autotrophs 51% (NPP_t) remained for natural ecosystems [14]. Consequently, any further take-out from the flow will reduce the energy available for natural ecosystems and increase the pressure on them. Thus, planning should be very careful if we are about to exploit new sustainable biomass resources.

The equation below defines the sustainably available potential:

$$sustainable\ potential = physical\ potential \cdot (0{,}5\ or\ other\ determinants)$$
$$available\ technical\ potential = technical\ potential - competitive\ uses$$
$$sustainable\ available\ potential = sustainable\ potential \cap available\ potential$$

Following the methodology in the first step, the task was to select the target area (Fig.4). To this end the area of arable and woodlands from the Corine Land Cover 2006 database was selected to each county, and legally protected and EU protected Natura 2000 areas were deducted (Tab. 1). The first selection criterion was the area of forest as the most favourable raw material for the biorefinery is deciduous wood. Therefore we wanted this resource to be planned with the possibly highest share in the input mix. Then we chose the four neighbouring counties (Baranya, Somogy, Tolna and Zala) with the largest area of woodland and arable land to reach the largest physical potential possible. These four counties were further analysed. In order to get the physical potential the average yield were determined both for forest and straw and multiplied by the available area.

Table 1. Detailed land use data of the target region

	Arable land (ha)	Share of arable land (%)	Forest land (ha)	Share of forest land (%)
Not protected	840 080	95,07	252 143	54,94
High Nature Value (HNV) Area	12 962	1,47	0	0
Natura2000	21 403	2,42	131 002	28,54
Protected	2 510	0,28	1 221	0,27
HNV+Natura2000	579	0,07	0	0
Protected Natura2000	5 450	0,62	74 583	16,25
Protected HNV	97	0,01	0	0
Protected HNV + Natura2000	572	0,06	0	0
Total	883 654	100,00	458 948	100,00

Based on forestry data [18] the annual yield of woodlands was calculated, of which only the firewood share was considered. To determine the average annual amount of the total yield the 5 year average of forestry yield was used since the production from year to year is not even. The other group of raw materials is straw and corn stover. The physical potential can be calculated by multiplying the total harvested yield [15] with the grain-stalk ratio of the corresponding crop [1,24]. To eliminate the fluctuation in annual yields we took the 3-year average in the calculations.

In the next step we calculated the technical potential. The technical potential of wood was calculated by considering only hardwood (i.e. broadleaf) fraction of the physical potential. We estimated the share of firewood in the total yield to be 60% and supposed that all of the broadleaf fraction of firewood is harvestable. Considering the 40% moisture content of the expected yield we calculated the yield in dry matter. This technical potential is supposed to be equal to the ecologically sustainable potential as the forestry yield plans are developed according to sustainable management principles. To get the technical potential the straw amount remaining on the stubble was deducted from the physical potential. The amount of stubble straw was calculated from the estimated 10 cm stubble height and the grain-stalk ratio of the corresponding crop (Tab. 2) provided that the consistence of the stalk is the same along the whole length.

Table 2. Straw waste ratio of different crops [24]

	Length of stem (m)	Height of stubble (m)	Waste ratio (%)	Sustainable harvestable share (%)
Wheat	0.90	0.10	11%	33%
Rye	1.80	0.10	6%	33%
Triticale	1.50	0.10	7%	33%
Maize	2.00	0.10	5%	33%
Sorghum	2.00	0.10	5%	33%

After the calculation of the physical and technical potential the next step is to determine the available technical potential by deducting biomass demands of competing uses from the technical potential. Here we considered all industries and households that use the same resource (Fig. 4). Consequently, the district heating units for instance in the study area would supply their fire wood demands from the above calculated technical potential. In the case of straw both the demands of energetics and bedding straw were deducted in our calculations.

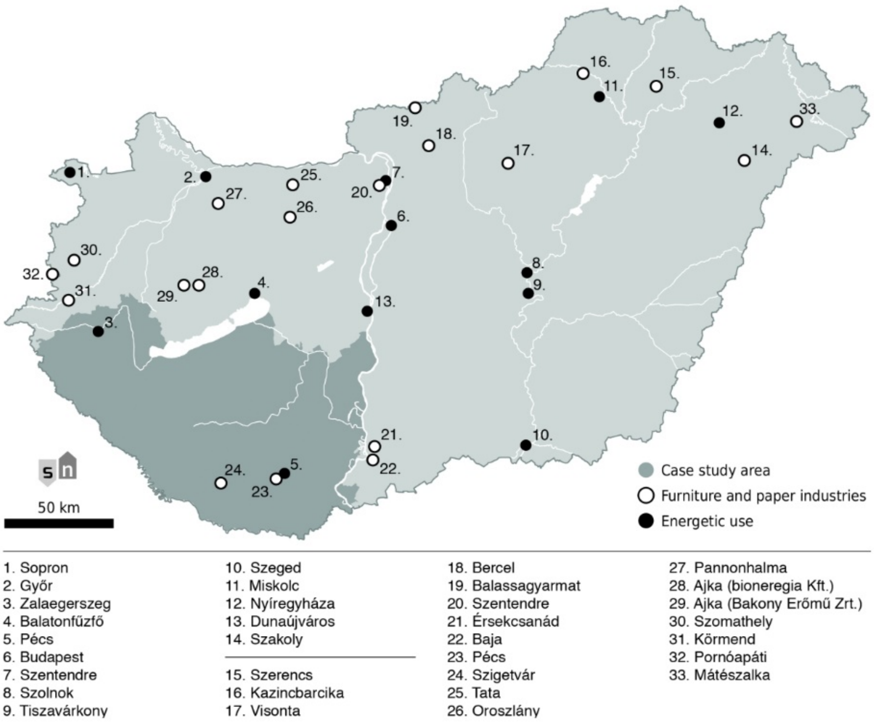

Figure 4. Case study area and biomass firing units and biomass utilization factories in Hungary

The bedding straw demand was calculated from the following parameters: number of animals in the study area [15], daily bedding straw demand specific by livestock type [19] and number of days of bedding [13] (Tab. 3).

Table 3. Bedding needs of selected livestock [13, 19]

Livestock	Mode of housing	Average bedding need (kg/LSU/day)	Bedding days per year (day)
Cattle	free litter	6.0	185
	bounded litter	3.0	185
Pig		6.0	365
Sheep		7.0	125
Horse		4.5	185

Having deducted the demands of currently competing uses from the technical potential the available technical potential is given. The calculation, however, raises a few problems and requires some assumptions to be made. It cannot be explicitly determined to what percentage the technical potential in question is present and how it is changing over time in the portfolio of a certain competing use. Moreover, it is not possible either to identify what percentage of biomass demand of a certain competing use originates from the target area.

To minimize the effects of the above uncertainties the following assumptions were made:

1. The biomass quality and quantity equal to the technical potential calculated from the known part of the portfolio of competing uses is entirely used by the competing plant. This assumption also means for the

economic potential that the competing uses can pay at least the same price for the raw material, i.e. the competing plants are at least in the same economic position as the planned biorefinery.

2. The competing plants gain their raw material supply 100% from the study area.
Since in determining the ecologically sustainable potential of straw and stover production the soil organic carbon (SOC) content is one of the most important criterion, the sustainability criteria for straw and stover were fine-tuned by considering requirements for SOC maintenance. The SOC reduction is 0.27 t C/ha/year for straw and 0.35 t C/ha/year for corn stover, when they are harvested [3]. Ref. [22] also proved the explicit decrease in SOC when corn stover is removed from site. At the same time there is considerable increase in SOC when the stover residues are left on the field. Thus, in order to maintain the SOC we calculated only with 33% of the total straw and stover harvest as residues left on the stubble increase the SOC to a higher degree than the degree of reduction caused by harvesting these by-products [22]. As a result, this calculated amount was considered a sustainable potential.
Another important factor is the fertilizing effect of straw ranging from 1.5-4.5 kg N/t dm [3] that on the other hand may reduce the environmental effect of chemical fertilizers produced with fossil energy if it is reincorporated into the soil. On the other hand, the decomposition of the straw increases GHG emission [3]. These factors, however, were not considered in our calculations.
After deducting the demands of competing uses the available potential is the result. The intersection of the available technical potential and sustainable potential gives the category of biomass that can be sustainably used for biorefinery purposes in the target region, i.e. the sustainable available potential.
The third source of raw materials is from short rotation coppice (SRC). The physical potential of this source was calculated from the area of current plantations (3748 ha) and average yield [9]. The average annual yield was considered in dry matter (9 t/ha) with supposing 40% moisture content.
Of the ecologically sustainable biomass potential we consider an amount socially sustainable whose quantity and nature of use is acceptable for the concerned community. The socially sustainable potential can only be determined if local inhabitants are involved in the planning process. The optimal level of public participation is therefore decisive from the viewpoint of social sustainability.
The final category is economic sustainability. This involves an economic and profitable production that should be sustainable from ecological and social aspects at the same time. In the concept of strong sustainability [7] resources are not substitutes for but rather complementary to each other.

3. RESULTS AND DISCUSSION

3.1. Feedstock potentials

The plant is able to take woodchips from broadleaf forest and SRC with a minimized fraction of bark. Additionally, straw and corn stover can be processed too.
Based on the methodology described above, the calculation of the physical potential of the broadleaf wood supply on an area of 408,718.4 ha yields almost 2.1 million m^3 wood/yr with 40% moisture content equalling to 843,416 t dm wood/yr. Determining the harvestable technical potential the firewood share of the physical potential was calculated that is 506,050 t dm firewood/yr. Deducting the competitive uses like power plant, district heating and households (altogether 470,510 t dm/yr), it turns out that the available technical potential of broadleaf forests is 35,540 t dm firewood/yr.
In the case of the next feedstock (straw and stalk) first also the physical potential was calculated, where 15% of moisture content was considered. It gives then the total amount of harvested straw (3,7 million t dm/yr). Deducting harvest wastes we gain the technical potential of 3,4 million t dm/yr. When subtracting the competitive uses of firing, bedding for animal husbandry and the necessary amount of sustaining SOC (2/3 of the physical potential), the available technical potential shrinks to 0.66 million t dm/yr.
In the case of SRC poplar the current cultivation area is not sufficient to cover the share of the biorefinary demand, an extra 8.856 t dm is needed. This amount considering a two years rotation can be cultivated on 1970 ha which requires a rather large land transformation from conventional cultivation, in the short run this deficit could be covered by straw and stover.
The feedstock input of the plant has been standardized for planning reasons, however, the portfolio is defined according to the available feedstock. In the target region, since the highest share of the technical potential is given by straw and corn stover, 60% of the feedstock is from these reources, 20% is firewood and 20% stems from SRC plantations, mainly poplar.

Considering the demand of the plant in the given 60-20-20% portfolio, the target region can provide the necessary amount in the given feedstock, with straw being the most abundant resource. The results are summarized in Fig. 5.

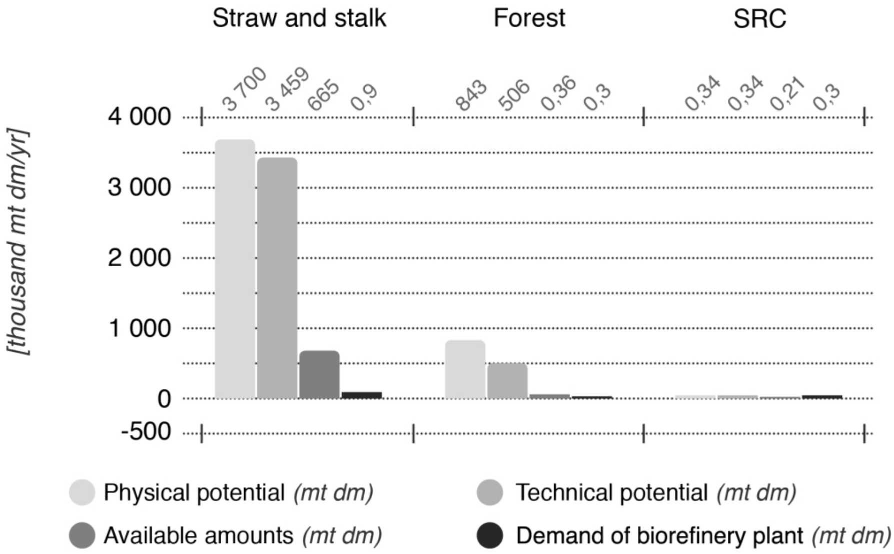

Figure 5. Available potentials

To assess the ecological effect the HANPP model was used. According to the previous calculations for Hungary the net primary production (NPP) is 13.3 $MJ/m^2/year$ for forests and 9.2 $MJ/m^2/year$ for grasslands [14]. In the case of forests this equals to 7,2 t DM/ha/yr NPP if 18,5 MJ/kg dry matter energy content is assumed [16]. When considering the total forest area in the target area and the total average yield (Tab. 4) from the forestry database, the HANPP is 28%. This is a favourable value when compared to the 50% assumed sustainability ceiling. If the planned plant will not use more firewood than the permitted felling of the forestry management plans, then the use of this source can be considered sustainable.

Table 4. Results of HANPP calculations for forest

Forest average productivity (t dm/yr)	7.2
Total forest area (ha)	458 950.8
Total forest production (t dm/yr)	3 299 484.1
Total harvest (t dm/yr)	917 854.8
Share of harvest (%)	28

In the case of arable lands the calculation of above ground NPP_0 (NPP_0: NPP of the potential terrestrial vegetation) is a result of the total harvested yield and the stover residues (NPP_h:NPP harvested or destroyed) [14]. The total of grain and straw is 5.7 million t dm, from which the total grain volume and the current and planned uses of straw (Tab. 5) mean the consumption. The harvested grain and straw is 47% of the total yield which is very close to the sustainability limit (50%).

Table 5. Results of HANPP calculations for straw

NPP_0 (t dm/yr)	5 691 906
NPP_h corn (t dm/yr)	1 991 276
NPP_h straw (t dm/yr)	702 208
Share of harvest (%)	47
Total straw need (t dm/yr)	702 208
of which	
bedding need (t dm/yr)	372 208
power plant (t dm/yr)	240 000
biorefinery (t dm/yr)	90 000

3.2. Results of the stakeholder meeting

In order to focus on the social acceptance and gather local knowledge from expertise, a stakeholder meeting was held. The results of the stakeholder meeting are as follows.

Uncertainty stems from the high variability of yields due the high diversity of cultivation conditions in the target region futher mitigated by unexpected weather effects. The target area is a hilly region, thus the available area for energy plantations is limited. Not just elevation but related water shortages can also hinder successful cultivation.

Forests in Zala county have the best conditions and highest yields in Hungary. The target region has a total yield of approx. 1 million m^3. Forest cover in the target region reaches 25 %. Although, a considerable amount of the forest harvest, especially from Zala, is exported to Austria. Here, the accession of Croatia to the EU also creates an extra demand. Additionally, common property forests are impossible to manage which again reduce the production potential. Around the power plant in Pécs with a diameter of 50-70 km it is impossible to find enough feedstock because the plant collects all available materials. The weak road network is also a limiting factor.

Stakeholders stated that it is rather problematic to cover the straw demand necessary for the power plant within the four counties that are identical with our target region. Here transportation impossibilities also excluded some available feedstock.

Concerning straw demand, with the planned biorefinery industry there is not much space for future growth in animal husbandry which has been dwindling activity until very recently. However, there are strong political initiatives that intend to reverse this trend and to establish a more balanced relation between plant production and animal husbandry. There are already signs in the target region that the number of animals will be increased considerably (by hundred thousand in the case of cow and swine), which will require a higher share of the straw than it is available currently.

The planning approach has been criticized by stakeholders for still being a top-down driven approach neglecting local demands, as their aim is market-oriented agricultural production.

A 150,000 t dm/yr input sized plant seems to be too large for the region.

There are additional competing uses emerging in the region (pellet and briquette production in Belezna, Kapuvár and other settlements in Bakony, biomass power plants in Gellénháza, Nagypáli, and an additional straw firing unit in Söjtör). The realization of these units will further shrink the possibilities of the planned biorefinery plant.

The majority of stakeholders accepts the biorefinery as a promising solution for substituting fossil based plastics; however, a balanced agricultural production including higher shares of husbandry is considered to gain priority. As a result, smaller refinery units adjusted to local demands and sustainable feed-stock potential should be a more acceptable alternative.

3.4. Sensitivity analysis

In order to incorporate stakeholders' opinions we developed an extreme scenario, where two important negative effects are considered: growth in bedding needs of an expanding husbandry sector and yield fluctuations due to weather extremes.

The recent statistics (2010) of livestock is irrationally low, it does not reach half the value of the year (1988) when it was the highest in the last 100 years. If we assume that the number of current livestock will increase and reach the level of 1988 (as a maximum), then it means a 250% change to cattle, 262% to pigs and 187% to sheep numbers. As a result, the bedding straw demand will increase from 370,000 metric tons to 947,000 tons.

Climate change is a further uncertainty factor. Both drought and floods can substantially reduce expected yields. However, due to elevation characteristics the effect of floods are negligible in the target region, only drought is a threatening factor.

No forecast data were available for the degree and frequency of drought and its effects on yield. Therefore, a series of yield data from previous years and historical data of yield decreases in years of drought were used to create a worst scenario. The yields in years with drought (2003, 2007) were assumed for 2025 that means 26-43% reduction in yield depending on crop. Assuming this extreme effect by 2025, 26% yield loss in cereals and an average 43% yield loss in corn is expected. We also assume that the amount of straw and stover is decreasing to the same degree as grain loss. Similar calculations for forestry, due to data shortage, could not be carried out.

This yield loss together with the increase in animal numbers will modify the available biomass potential as shown in Fig. 6.

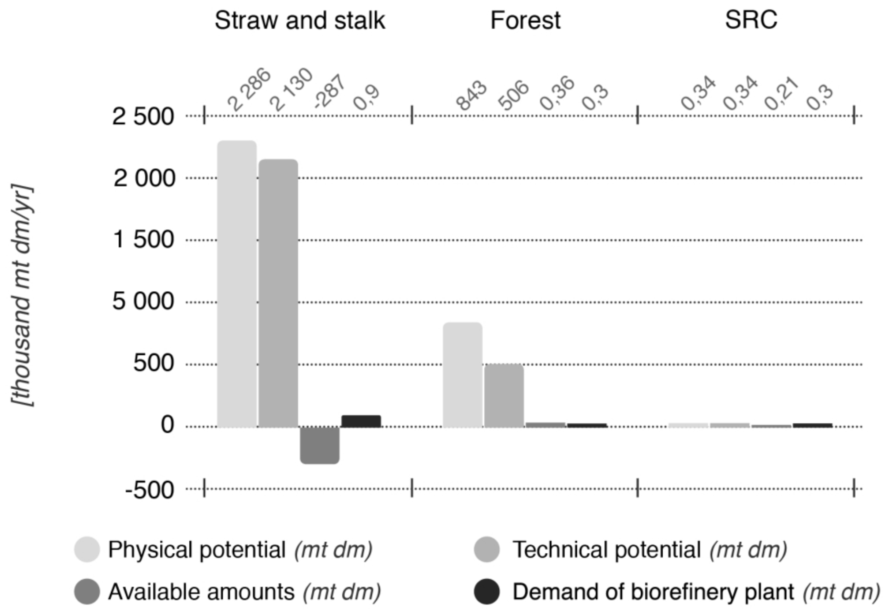

Figure 6. Available potentials according to the worst case scenario

It is apparent that the raw material previously available in the largest quantities will diminish due to the anticipated changes and will not be able to meet even a 90,000 t/yr of straw and stover biorefinery demand. Consequently, the demand and competition will increase for the available firewood and the ratio of feedstock sources would have to be modified from the currently planned 60:20:20. As a result, the quantity of firewood would also drop to a minimum, and pressure increased on the still protected forest and arable land sites. Additionally, the criteria of sustainable production might also be violated more frequently, like collecting more straw and stover than 33% of the total harvest. The situation could be improved if the area of energy crops was increased but this might be limited by the increasing needs for food and fodder.

4. SUMMARY

We conclude that among current circumstances, and with the necessary development of SRC envisaged, there is enough feedstock for a 150,000 metric tons dm/year input capacity biorefinery plant. In the feedstock portfolio 60% is straw and corn stover, 20% is firewood and 20% stems from SRC plantations, mainly poplar.

Future changes, however, may substantially overwrite the picture of the currently abundant feedstock.

Forestry yield loss due to drought is a main threat to broadleaf feed stocks but increase in demands from other sectors for certain forestry categories is also foreseen. Uncertainty also stems from the high

variability of yields due the high diversity of cultivation conditions in the target region further exacerbated by unexpected weather effects and climate change. The target area is a hilly region, thus the available area for energy plantations is limited. Not just elevation but related water shortages can also hinder successful cultivation.
Additional competing uses are also emerging in the region (pellet and briquette production, biomass power plants, straw firing units) and also encouraged by national initiatives (e.g. to reverse the recently diminishing trend of livestock husbandry) which also put pressure on straw as feedstock availability in the long run.
Although the planning approach was still criticized by stakeholders to be top-down driven, the majority accepts biorefinery in general as a promising solution for substituting fossil based plastics. As a result, a balanced agricultural production including higher shares of husbandry and market-oriented agricultural production as local aims are to be given priority. Consequently, a smaller refinery units adjusted to local demands and sustainable feed-stock potential shall be a more acceptable alternative.

ACKNOWLEDGEMENT

This paper is based on the work of a multidisciplinary project ‘Biocommodity refinery’ that has received funding from the European Community’s Seventh Framework Programme (FP7/ 2007- 2013) under grant agreement No. 241566. The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission. Further details are available at www.biocore-europe.org. We thank all members of the stakeholder and technical panels that provided invaluable input and advice throughout the case study process.

REFERENCES

[1] Antal, J. 2000. Növénytermesztők zsebkönyve. Mezőgazda kiadó. Budapest

[2] Arnstein, S.R. (1969): A Ladder of Citizen Participation. J. of the American Planning Association. 35(4), 216-224.

[3] Cherubini, F. ; Ulgiati, S. 2010. Crop residues as row materials for biorefinery systems – A LCA Case Study. Applied Energy 87/47-57.

[4] Corine Land Cover 2006. Geographical Data Base

[5] Ćosić, B., Stanić, Z., Duić, N. 2011. Geographic distribution of economic potential of agricultural and forest biomass residual for energy use: Case study Croatia. Energy 36 pp. 2017-2028

[6] Devine-Wright, P. (ed.) 2011. Renewable Energy and the Public. From NIMBY to Participation. Earthscan London p. 336

[7] van Dieren, W. ed. 1995. Taking Nature into Account. A Report to the Club of Rome. Copernicus Springer-Verlag New York, p. 332.

[8] Giampietro, M.; Pimentel, D. 1994. The tightening conflict: population, energy use and the ecology of agriculture. http://www.dieoff.com/page69.htm. Date of download 2007.01.21.

[9] Gockler, L. 2010. Fás szárú energiaültetvények a mezőgazdaságban. Mezőgazdasági technika, 2010/November. pp. 40-43.

[10] Haberl, H., Erb, K.-H., Krausmann, F., Gaube, V., Bondeau, A., Plutzar, C., Gingrich, S., Lucht, W., Fischer-Kowalski, M., 2007. Quantifying and mapping the human appropriation of net primary production in earth's terrestrial ecosystems. Proceedings of the National Academy of Sciences of the United States of America 104:12942-12947.

[11] Haberl, H.; Geissler S. 1999. Cascade utilisation of biomass: strategies for a more efficient use of a scarce resource. Ecological Engineering 16, 111-121

[12] Haberl, H., Schulz N. B., Plutzar Ch., Erb K. H., Krausmann F., Loibl W., Moser D., Sauberer N., Weisz H., Zechmeister H. G., Zulka P. 2004. Human appropriation of net primary production and species diversity in agricultural landscapes. Agriculture, Ecosystems and Environment 102, pp. 213–218

[13] Kismányoki T. Szervestrágyázás. In: Nyír L. ed. Földműveléstan. 1993. Mezőgazdasági kiadó, Budapest

[14] Kohlheb, N, Krausmann, F. 2009. Land use change, biomass production and HANPP: The case of Hungary 1961–2005. Ecological Economics 69 (2009) pp. 292–300

[15] KSH (Hungarian Central Statistical Office) 2012. Agricultural yields. Budapest

[16] Loo, van S., Koppejan, J. ed. 2008. The Handbook of Biomass Combustion & Co-firing. Earthscan, London

[17] MEH (Hungarian Energy Authority). A 2008. évi erőművi biomassza felhasználás ellenőrzése. Budapest

[18] MGSzH (National Forestry Service) 2012. Regional forest yields. Budapest

[19] Müller L. ed. Szervestrágya gazdálkodás. Budapest 1990 Agroinform kiadó. Budapest

[20] Pfeiffer, D.A. 2004. Eating Fossil Fuels. The Wilderness Publications, www.copvcia.com. Date of download 2007.01.21.

[21] Rosillo-Calle, F., de Groot, P., Hemstock, S.L., Woods, J. (ed.) 2007. The Biomass Assessment Handbook. Bioenergy for a Sustainable Environment. Earthscan London p. 269

[22] Sheehan, J., Aden, A., Paustian, K., Killian, K., Brenner, J., Walsh, M., Nelson, R. 2004. Energy and Environmental Aspects of Using Corn Stover for Fuel Ethanol. Journal of Industrial Ecology 7/3-4, pp. 117-146

[23] Steubing, B., Zah, R., Waeger, P. Ludwig C. 2010. Bioenergy in Switzerland: Assessing the domestic sustainable biomass potential. Renewable and Sustainable Energy Reviews 14, pp. 2256–2265

[24] Tirczka, I. 2010. 'Personal communication'. Gödöllő

[25] Voivontas, D., Assimacopoulos D., Koukios, E.G. 2001. Assessment of biomass potential for power production: a GIS based method, Biomass and Bioenergy 20, pp. 101-112

[26] Wright, D.H., 1987. Estimating human effects to global extinction. Int. J. Biometeorol. 31, 293–299.

[27] Wright, D.H., 1990. Human impacts on the energy flow through natural ecosystems, and implications for species endangerment. Ambio 19, 189–194.